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MEASUREMENTS OF NUCLEAR PARAMETERS OF HIGH-Z ISOTOPES PERFORMED ON THE LIVERMORE HIGH-ENERGY ELECTRON BEAM ION TRAP

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The trapping and production of highly charged ions in a high-energy electron beam ion trap creates new opportunities for nuclear physics experiments. Highly charged, few-electron ions have a simplified electronic structure so that spectroscopic measurements can, in principle, provide information on nuclear parameters with much higher accuracy than measurements involving atoms or singly charged ions. The ions are stationary and their temperature can be decoupled from the energy of the electron beam by several orders of magnitude [1], enabling very high-resolution, Doppler-shift-free measurements. Moreover, because ion traps generally require only minute quantities of material for filling, they are well suited for investigating the properties of isotopes that are rare or radioactive. Several measurements of nuclear parameters have now been made with our high-energy electron beam ion trap.

Employing high-resolution x-ray spectroscopy of the n=2 to n=2 x-ray transitions in nearly bare uranium ions (U^{86+}, U^{87+}, U^{88+}, and U^{89+}) we have studied the isotopic variation of the nuclear charge distribution among the isotopes ^{233}U, ^{235}U, and ^{238}U. The isotopic variation of the nuclear charge distribution, a fundamental parameter crucial for understanding the collective structure of the nucleus and parameterized in terms of the change in mean-square nuclear charge radius $\delta\langle r^2\rangle$, has been inferred in the high-Z region from muonic-atom x rays and neutral-atom optical isotope shift studies. Earlier measurements of $\delta\langle r^2\rangle$ between ^{233}U and ^{238}U, for example, had produced discrepant results, i.e. -0.520 ± 0.081 fm^2 [2] and -0.383 ± 0.044 fm^2 [3,4]. We measured $\delta\langle r^2\rangle^{233,238} = -0.457$ fm^2 with an uncertainty of 0.043 fm^2 [5]. The uncertainty was completely dominated by a statistical uncertainty of 0.042 fm^2, suggesting that measurements with higher accuracy will be possible in the future.

Employing high-resolution spectrocopy in the visible, we have measured the hyperfine transition between F=4 and F=3 in hydrogenic $^{165}Ho^{66+}$ at 5726.4±1.5 Å [6]. The measured value differs by 89 Å from a recent prediction [7]. This discrepancy could be attributed to an inaccurate value of the nuclear magnetic moment tabulated in the literature. Measurements of the hyperfine transition can thus be used to distinguish between discrepant values of the nuclear magnetic moments. Unfortunately, several atomic physics contributions to the transitions energy are not yet fully calculated and thus limit the accuracy with which the nuclear magnetic moment can be inferred from such a measurement.

In order to expand the range of materials we can study in our device, we performed experiments with transuranic elements. We successfully introduced ^{249}Cf into our trap and observed x radiation from few-electron californium ions. This is the first demonstration that transuranic elements can be studied in a high-energy electron beam ion trap and points the way for future nuclear physics measurements.

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